

CLAIMS

Therefore, having thus described the invention, at least the following is claimed:

- 1 1. A composition, comprising:
2 a metal nitrate selected from d-block metal nitrates and f-block metal
3 nitrates; and
4 a metal salt having weakly bound counter anions, wherein the metal of the
5 metal salt having weakly bound counter anions is selected from a d-block metal
6 and an f-block metal.

- 1 2. The composition of claim 1, wherein the metal nitrate is selected from iron (III)
2 nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate
3 and cerium (IV) nitrate.

- 1 3. The composition of claim 1, wherein the metal salt having weakly bound counter
2 anions is selected from copper (II) perchlorate, copper (II)
3 trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

- 1 4. The composition of claim 1, wherein the metal nitrate is selected from iron (III)
2 nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate
3 and cerium (IV) nitrate, and wherein the metal salt having weakly bound counter
4 anions is selected from copper (II) perchlorate, copper (II)
5 trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

- 1 5. The composition of claim 1, wherein the metal nitrate is copper nitrate and the
2 metal salt having weakly bound counter anions is copper
3 trifluoromethanesulfonate.

- 1 6. The composition of claim 1, further comprising a polyoxometalate.

1 7. The composition of claim 6, wherein the polyoxometalate has the formula
 2 $A[V_k Mo_m W_n Nb_o Ta_p M_q X_r O_s]^{y-}$, wherein A includes at least one counterion selected
 3 from alkali metal cations, alkaline earth metal cations, ammonium cations,
 4 quaternary ammonium cations, d-block cations, f-block cations, and combinations
 5 thereof, wherein M includes at least one element selected from an f-block element
 6 and a d-block element having at least one d-electron, except for vanadium,
 7 molybdenum, tungsten, niobium, or tantalum, wherein X includes at least one
 8 element selected from a p-block element, a d-block element, and an f-block
 9 element, except for oxygen, wherein k can range from 0 to 30, wherein m can
 10 range from 0 to 160, wherein n can range from 0 to 160, wherein o can range from
 11 0 to 30, where p can range from 0 to 10, wherein q can range from 0 to 30,
 12 wherein r can range from 0 to 30, wherein s is a number so that y is greater than
 13 zero, wherein the sum of k, m, n, o, and p is greater than or equal to four; and
 14 wherein the sum of k, m, and q is greater than zero.

1 8. The composition of claim 6, wherein the polyoxometalate has the formula
 2 $[X^g V_b^{j+} M_c^{h+} Z_{12-b-c}^{i+} O_x]^{u-}[A]$, wherein X is at least one p-, d-, or f-block element; g
 3 is greater than or equal to 2; M is at least one f-block element or d-block element
 4 having at least one d-electron, wherein M is not vanadium; h is from 1 to 7; i is
 5 from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten, molybdenum, niobium, or
 6 a combination thereof; b is from 0 to 6; c is from 0 to 6; u is from 3 to 9; and A is
 7 a counterion.

1 9. The composition of claim 6, wherein the polyoxometalate has the formula
 2 $[X^g V_b^{j+} Z_{12-b}^{i+} O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon, aluminum,
 3 boron, zinc, cobalt, or iron; b is from 1 to 6, and a is from 3 to 9.

1 10. The Composition of claim 6, wherein the polyoxometalate has the formula
 2 $[X^g M_c^{h+} Z_{12-c}^{i+} O_{40}]^{u-}[A]$, wherein X is at least one of phosphorus, silicon,
 3 aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a is from 3 to 9.

- 1 11. The composition of claim 6, wherein the polyoxometalate has the formula
2 $[X_2^{r+}V_u^{s+}M_v^{t+}Z_{18-u-v}^{y+}O_z]^{w-}[A]$, wherein X is at least one p-, d-, or f-block element; r
3 is greater than or equal to 1; M is at least one f-block element or d-block element
4 having at least one d-electron, wherein M is not vanadium; t is from 1 to 7; s is
5 from 4 to 5; Z is tungsten, molybdenum, niobium, or a combination thereof; a is
6 from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or 62; w is greater than or
7 equal to 4; and A is a counterion.
- 1 12. The composition of claim 6, wherein the polyoxometalate has the formula
2 $[X_2^{r+}V_u^{s+}Z_{18-u}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon,
3 aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9; and w is greater than or
4 equal to 4.
- 1 13. The composition of claim 6, wherein the polyoxometalate has the formula
2 $[X_2^{r+}M_v^{t+}Z_{18-v}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one of phosphorus, sulfur, silicon,
3 aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is greater than or
4 equal to 4.
- 1 14. The composition of claim 6, wherein the polyoxometalate has the formula
2 $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or aluminum; Z is tungsten or
3 molybdenum; p is from 1 to 6, and A is a counterion.
- 1 15. The composition of claim 6, wherein the metal nitrate is selected from iron (III)
2 nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate
3 and cerium (IV) nitrate.
- 1 16. The composition of claim 6, wherein the metal salt having weakly bound counter
2 anions is selected from copper (II) perchlorate, copper (II)
3 trifluoromethanesulfonate, and copper (II) tetrafluoroborate.

- 1 17. The composition of claim 6, wherein the metal nitrate is selected from iron (III)
2 nitrate, cobalt (II) nitrate, nickel (II) nitrate, copper (II) nitrate, cerium (III) nitrate
3 and cerium (IV) nitrate, and wherein the metal salt having weakly bound counter
4 anions is selected from copper (II) perchlorate, copper (II)
5 trifluoromethanesulfonate, and copper (II) tetrafluoroborate.
- 1 18. The composition of claim 6, wherein the polyoxometalate is selected from
2 $\text{TBA}_6\text{Fe}_3\text{PW}_9\text{O}_{37}$, wherein TBA is tetra-*n*-butylammonium; $\text{TBA}_6\text{V}_{10}\text{O}_{28}$,
3 $\text{TBA}_3\text{PV}_2\text{Mo}_{10}\text{O}_{40}$; $\text{TBA}_6\text{Fe}_3\text{PW}_9\text{O}_{37}$; $\text{TBA}_9\text{Fe}_3(\text{A-PW}_9\text{O}_{34})_2$; and
4 $\text{TBA}_{12}\text{Fe}(\text{OH}_2)_2\text{Fe}_2(\text{P}_2\text{W}_{15}\text{O}_{56})_2$.
- 1 19. The composition of claim 18, wherein the metal nitrate is copper nitrate and the
2 metal salt having weakly bound counter anions is copper
3 trifluoromethanesulfonate.
- 1 20. The composition of claim 1, wherein the composition is included in a material.
- 1 21. The composition of claim 6, wherein the composition is included in a material.
- 1 22. The composition of claim 20, wherein the material being selected from a fabric, a
2 topical carrier, powder, and a coating.
- 1 23. The composition of claim 21, wherein the material being selected from a fabric, a
2 topical carrier, powder, and a coating.
- 1 24. A method of removing a contaminant, comprising:
2 contacting the composition of claim 1 with the contaminant.
- 1 25. The method of claim 24, wherein the composition is included in a material.

- 1 26. The method of claim 25, wherein the material being selected from a fabric, a
2 topical carrier, powder, and a coating.
- 1 27. A method of removing a contaminant, comprising:
2 contacting the composition of claim 6 with the contaminant.
- 1 28. The method of claim 27, wherein the composition is included in a material.
- 1 29. The method of claim 28, wherein the material selected from a fabric, a topical
2 carrier, powder, and a coating.
- 1 30. A composition, comprising:
2 a first polyoxometalate having a first metal selected from a d-block metal
3 and an f-block metal, wherein the first metal being an open coordinate site of the
4 first polyoxometalate, and wherein the first metal has a nitrate terminal ligand; and
5 a second polyoxometalate having a second metal selected from a d-block
6 metal and an f-block metal, wherein the second metal being an open coordinate site
7 of the second polyoxometalate, and wherein the second metal has a halide terminal
8 ligand.
- 1 31. The composition of claim 30, wherein the halide terminal ligand is a bromide
2 terminal ligand.
- 1 32. The composition of claim 31, wherein the second metal is selected from iron (III)
2 and copper (II).
- 1 33. The composition of claim 32, wherein the first metal is selected from iron (III),
2 copper (II), cerium (III), and cerium (IV).

- 1 34. The composition of claim 30, wherein the first metal is selected from iron (III),
2 cobalt (II), nickel (II), copper (II), cerium (III), and cerium (IV).
- 1 35. The composition of claim 30, wherein the first metal is selected from iron (III),
2 copper (II), cerium (III), and cerium (IV).
- 1 36. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $A[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^{y-}$, wherein A includes at least one
3 counterion selected from alkali metal cations, alkaline earth metal cations,
4 ammonium cations, quaternary ammonium cations, d-block cations, f-block
5 cations, and combinations thereof, wherein M includes at least one element
6 selected from an f-block element and a d-block element having at least one d-
7 electron, except for vanadium, molybdenum, tungsten, niobium, or tantalum,
8 wherein X includes at least one element selected from a p-block element, a d-block
9 element, and an f-block element, except for oxygen, wherein k can range from 0 to
10 30, wherein m can range from 0 to 160, wherein n can range from 0 to 160,
11 wherein o can range from 0 to 30, where p can range from 0 to 10, wherein q can
12 range from 0 to 30, wherein r can range from 0 to 30, wherein s is a number so
13 that y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or
14 equal to four; and wherein the sum of k, m, and q is greater than zero.
- 1 37. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X^gV_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^{u-}[A]$, wherein X is at least one p-, d-, or f-block
3 element; g is greater than or equal to 2; M is at least one f-block element or
4 d-block element having at least one d-electron, wherein M is not vanadium; h is
5 from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten,
6 molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6;
7 u is from 3 to 9; and A is a counterion.

- 1 38. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X^g V_b^{j+} Z_{12-b}^{i+} O_{40}]^u [A]$, wherein X is at least one of phosphorus,
3 silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and a is from 3 to
4 9.
- 1 39. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X^g M_c^{h+} Z_{12-c}^{i+} O_{40}]^u [A]$, wherein X is at least one of phosphorus,
3 silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a is from 3 to
4 9.
- 1 40. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X_2^{r+} V_u^{s+} M_v^{t+} Z_{18-u-v}^{y+} O_z]^w [A]$, wherein X is at least one p-, d-, or
3 f-block element; r is greater than or equal to 1; M is at least one f-block element or
4 d-block element having at least one d-electron, wherein M is not vanadium; t is
5 from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium, or a
6 combination thereof; a is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or
7 62; w is greater than or equal to 4; and A is a counterion.
- 1 41. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X_2^{r+} V_u^{s+} Z_{18-u}^{y+} O_{62}]^w [A]$, wherein X is at least one of phosphorus,
3 sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9; and w is
4 greater than or equal to 4.
- 1 42. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[X_2^{r+} M_v^{t+} Z_{18-v}^{y+} O_{62}]^w [A]$, wherein X is at least one of phosphorus,
3 sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is
4 greater than or equal to 4.

- 1 43. The composition of claim 30, wherein the first polyoxometalate further comprises
2 the formula $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or aluminum; Z is
3 tungsten or molybdenum; p is from 1 to 6, and A is a counterion.
- 1 44. The composition of claim 30, wherein the second polyoxometalate further
2 comprises the formula $A[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^{y-}$, wherein A includes at least
3 one counterion selected from alkali metal cations, alkaline earth metal cations,
4 ammonium cations, quaternary ammonium cations, d-block cations, f-block
5 cations, and combinations thereof, wherein M includes at least one element
6 selected from an f-block element and a d-block element having at least one d-
7 electron, except for vanadium, molybdenum, tungsten, niobium, or tantalum,
8 wherein X includes at least one element selected from a p-block element, a d-block
9 element, and an f-block element, except for oxygen, wherein k can range from 0 to
10 30, wherein m can range from 0 to 160, wherein n can range from 0 to 160,
11 wherein o can range from 0 to 30, where p can range from 0 to 10, wherein q can
12 range from 0 to 30, wherein r can range from 0 to 30, wherein s is a number so
13 that y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or
14 equal to four; and wherein the sum of k, m, and q is greater than zero.
- 1 45. The composition of claim 30, wherein the second polyoxometalate further
2 comprises the formula $[X^gV_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^{u-}[A]$, wherein X is at least one p-, d-,
3 or f-block element; g is greater than or equal to 2; M is at least one f-block element
4 or d-block element having at least one d-electron, wherein M is not vanadium; h is
5 from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten,
6 molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6;
7 u is from 3 to 9; and A is a counterion.

1 46. The composition of claim 30, wherein the second polyoxometalate further
 2 comprises the formula $[X^g V_b^{j+} Z_{12-b}^{i+} O_{40}]^u [A]$, wherein X is at least one of
 3 phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and a
 4 is from 3 to 9.

1 47. The composition of claim 30, wherein the second polyoxometalate further
 2 comprises the formula $[X^g M_c^{h+} Z_{12-c}^{i+} O_{40}]^u [A]$, wherein X is at least one of
 3 phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and a
 4 is from 3 to 9.

1 48. The composition of claim 30, wherein the second polyoxometalate further
 2 comprises the formula $[X_2^{r+} V_u^{s+} M_v^{t+} Z_{18-u-v}^{y+} O_z]^w [A]$, wherein X is at least one p-,
 3 d-, or f-block element; r is greater than or equal to 1; M is at least one f-block
 4 element or d-block element having at least one d-electron, wherein M is not
 5 vanadium; t is from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium,
 6 or a combination thereof; a is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61
 7 or 62; w is greater than or equal to 4; and A is a counterion.

1 49. The composition of claim 30, wherein the second polyoxometalate further
 2 comprises the formula $[X_2^{r+} V_u^{s+} Z_{18-u}^{y+} O_{62}]^w [A]$, wherein X is at least one of
 3 phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; a is from 1 to 9;
 4 and w is greater than or equal to 4.

1 50. The composition of claim 30, wherein the second polyoxometalate further
 2 comprises the formula $[X_2^{r+} M_v^{t+} Z_{18-v}^{y+} O_{62}]^w [A]$, wherein X is at least one of
 3 phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9;
 4 and w is greater than or equal to 4.

- 1 51. The composition of claim 30, wherein the second polyoxometalate further
2 comprises the formula $[YV_pZ_{12-p}O_{40}][A]$, wherein Y is phosphorus, silicon, or
3 aluminum; Z is tungsten or molybdenum; p is from 1 to 6, and A is a counterion.
- 1 52. The composition of claim 34, wherein the first polyoxometalate is selected from
2 $TBA_{9-x}H_x[A-\alpha-(Fe(NO_3))_3PW_9O_{37}]$, $TBA_{12-x}H_x[A-\alpha-(Cu(NO_3))_3PW_9O_{37}]$,
3 $TBA_{9-x}H_x[A-\alpha-(Ce(III)(NO_3))_3PW_9O_{37}]$, and
4 $TBA_{6-x}H_x[A-\alpha-(Ce(IV)(NO_3))_3PW_9O_{37}]$.
- 1 53. The composition of claim 44, wherein the second polyoxometalate is
2 $TBA_{12-n-x}Na_n[A-\alpha-(CuBr)_3PW_9Br_xO_{37-x}]$ and
3 $TBA_{12-n-x}Na_n[A-\alpha-(FeBr)_3PW_9Br_xO_{37-x}]$.
- 1 54. The composition of claim 30, wherein the composition is included in a material.
- 1 55. The composition of claim 54, wherein the material selected from a fabric, a topical
2 carrier, powder, and a coating.
- 1 56. A method of removing a contaminant, comprising:
2 contacting the composition of claim 30 with the contaminant.
- 1 57. The method of claim 56, wherein the composition is included in a material.
- 1 58. The method of claim 57, wherein the material selected from a fabric, a topical
2 carrier, powder, and a coating.